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Computerized order entry, clinical decision support, and safer prescribing

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Summary

Unintended harms from medicines caused by adverse drug reactions and medication errors are common. The medication process is very complex, and error can occur in the development, manufacture, distribution, prescribing, dispensing, administration, and monitoring of medicines. The prescriber, to avoid error, must first make careful decisions tailored to account for numerous factors that differ from patient to patient, then communicate orders that others must execute meticulously and whose consequences must be adequately monitored.

Introduction

Drug treatment for an individual should be as safe, effective, and cost-effective as possible. Rational therapeutics seeks to achieve an acceptable balance between maximal efficacy and maximal safety, and has sometimes been referred to as ‘balanced prescribing.’¹

The numerous factors that inform prescribing decisions, and the complexities of dispensing and administering the correct medicine in the correct way, place high technical and cognitive demands on those involved in the medication process. This inevitably makes the process error-prone.² A medication error is ‘*a[n unintentional] failure in the treatment process that leads to, or has the potential to lead to, harm to the patient,*’ where failure means that the treatment does not reach some attainable standard, and the treatment process runs from the prescribing decision onwards.^{3 4}

The burden of medication errors

The burden of medication errors is substantial, but neither the number of errors nor the number of opportunities for error is easily ascertained. It is even more difficult to know whether detected errors are important, since their consequences or potential consequences can differ from insignificant to fatal.⁵ A systematic review of computer-assisted prescribing in hospital included 16 articles.⁶ One early study observed errors during 4.9% of in-patient episodes,⁷ while studies in the Netherlands and Australia reported baseline error rates exceeding 99%.^{8 9} The Institute of Medicine in the US estimated rates of prescribing errors from 12.3 to 1400 per 1000 admissions, and of administration errors from 2.4 to 11.1 per 100 opportunities or doses; these wide ranges underline the uncertainties.¹⁰

The complexity of the medication process

The risks of human error are increased when tasks are complex or unfamiliar, and when their effects cannot immediately be appreciated. There are many opportunities for error in the medication process—one consensus analysis found 60 different types.¹¹ The analysis omitted errors in monitoring therapy, which contribute to serious harm in the use of gentamicin, for example.

The simplest prescribing decisions involve a consideration of the indication, that is, the reason for treatment; contra-indications, which are reasons why a medicine must not be given; warnings of precautions to be taken and risks to consider in the context of the

individual; special considerations such as the co-existence of more than one condition, concomitant treatments, or the prior experience and preference of the individual; the relevant form, dosage, route of administration, and duration of treatment; and the circumstances in which monitoring or stopping treatment are required. Around twenty pieces of information are needed to write (or generate) a single prescription on a routine hospital prescription chart to identify the prescriber, recipient (patient), medicine, and conditions of use. Information about the patient and their medication can be provided directly from the patient or their carers, in addition to hospital and general practice records and possibly the community pharmacist. However, the information is commonly incomplete, out-of-date, difficult to interpret, or inaccessible out of hours.

Computers and prescribing

Inevitably, hand-written prescription charts can be difficult to read, incomplete, and error-prone. The practice of using computers to type prescriptions (medication orders) in general practice was described in the 1980s, when computers for use by doctors were ‘still in their infancy despite their enormous potential.’¹² Computerized Physician Order Entry (CPOE) is now the norm in UK general practice, with the advantages that prescriptions are legible, essential information is present on all prescriptions, and general practitioners have comprehensive records of medicines prescribed. CPOE in hospitals is less common, but is rapidly increasing, encouraged by financial incentives from the NHS to drive the digitisation of care records.

Effects of CPOE

A US study estimated that CPOE reduced medication errors overall by about 50%; but the estimate of the number of medication errors prevented nationally ranged from 90 000 to 27.1 million per year.¹³ Rates have also been shown to fall in specialist settings such as critical care, with one study reporting a fall in error rate from 6.7% to 4.8% of prescriptions when CPOE without decision support replaced written prescriptions.¹⁴ However, dosage errors were found to increase. A potentially fatal intercepted error occurred when diamorphine was prescribed electronically using the pull-down menus at a dose of 7 mg/kg instead of 7 mg total, which could have led to a 70-fold overdose.

A study that examined errors specific to computerized prescribing in paediatrics identified one error per 100 patient-days that was specifically related to design features of the system

used.¹⁵ Seven of 20 identified errors were serious. These included duplicate prescriptions for paracetamol, a selection error leading to prescription of intraperitoneal rather than intravenous ceftriaxone, and a keypad error in which a dose was typed as 5 mg rather than 50 mg. The same research group, using interrupted time series analysis to examine errors before and after the introduction of a CPOE system, detected 70 non-intercepted serious medication errors during the periods of observation.¹⁶ CPOE reduced the rate by just 7%, and the rate of dosing errors, the most common form of paediatric medication error, did not fall, even though the system included automated weight-based dosage checking designed to prevent dosing errors.

Westbrook *et al* (2012) demonstrated that rates of ‘procedural’ errors—errors where prescriptions were incomplete, unclear, or non-compliant with the law or local regulations, fell from 8% to 0.5% of hospital admissions after the introduction of commercial prescribing systems.¹⁷ Their study, which did not explicitly state whether the systems incorporated decision support, found no overall reduction in ‘clinical’ errors, that is, errors in which correctly written prescriptions specified or omitted medicines in error, or where there was an error in the formulation, strength, dose, route, or other characteristic of the drug, or where a specified medicine interacted with or duplicated the actions of another. They did, however, record a statistically significant fall in the proportion of serious errors.

A review of 34 studies of errors with CPOE distilled the principal sources of error: poor computer display; uncritical acceptance of ‘help’ in the form of drop-down menus and auto-population of fields; poorly comprehensible wording; default settings that were not always appropriate; inflexible prescribing rules; ‘automatic’ functions, such as repeat prescribing; and incompatibility with the users’ work pattern.¹⁸ It is perhaps not surprising then a series of attributes of CPOE, including the way of ‘searching for the desired drug,’ how medications were displayed or described, and methods of ‘composing or entering the drug regimen’, have been described.¹⁹

Selection errors

There are advantages in presenting a drug dictionary of locally available medicines so that the first few letters of a drug name bring up a list of candidate preparations. However, the wrong drug formulation can be selected through technical error (clicking when the computer mouse is pointing to the wrong line) or misreading, or failure to read all available information. For

example, a patient came to harm when penicillamine 250 mg four times daily was prescribed in error for penicillin V 250 mg four times daily.²⁰

Clinical decisions support (CDS)

Instructions on the use of medicines can be complex.²¹ More generally, prescribers need information on the drug prescribed, its indications, contra-indications, dosing ('posology'), and potential interactions at the point of prescribing. CDS can provide warnings or alerts at the point of prescribing, which may be advisory, require action by the prescriber, or prevent the prescriber from proceeding altogether.^{22 23}

Systems can provide complex decision support, demonstrated by a detailed taxonomy of CDS tools developed to assess the capabilities systems to include: (1) medication dosing support (for example, maximum single dose checking...); (2) 'order facilitators,' that is, for example, complete prescription sentences or sets of prescriptions (order sets), where two or more drugs are commonly co-prescribed; (3) alerts and reminders, for example of possible drug–drug interactions; and provision of relevant information, such as patient test results; (4) expert systems that offer support, for example, in antibiotic choice; and (5) workflow support, such as structured discharge summaries.²⁴ Bates *et al* have set out the 'Ten Commandments for effective CDS.'²⁵ The first of these is that speed of interaction with the computer system is essential: a screen should change in less than one second. Also important is the ability to help at the point help is needed, rather than forcing the user to search for assistance.

The four CDS systems that account for about three-quarters of all systems used in UK general practices were tested against 18 medication safety scenarios, such as the inadvertent prescription of methotrexate tablets daily.²⁶ At the time of the study, no system displayed alerts for more than 7 of 18 scenarios. This justifies the assertion that computer-aided prescribing 'leaves holes in the safety net.'²⁷ A study of consultations in general practice found that of 117 alerts triggered by 81 prescriptions, only three were examined by the prescriber, and in no case was the prescription altered.²⁸ The authors characterized this CDS as 'too much, too late.'

Alerts

'Alert fatigue,' the tendency to ignore alerts, whether or not they are clinically relevant, is a danger if too many alerts are presented.²⁹ Some of the difficulties may be overcome by

grading alerts, so that interruptive alerts, which require action by the prescriber, are only triggered in clinically critical (high-risk) circumstances.^{30 31} A controlled study found that 100% of the most severe alerts were acted on at a site where interactions were graded, while only 34% were acted on at the comparator site where they were not.³²

Repeated assessment of the frequency with which alerts are triggered and prescribers' responses to these (i.e. accepted, overridden) may help identify whether the alerts are clinically useful.³³ In a simulation study, 20 prescribers compared a system before and after re-design. The average time to resolve alerts fell from 85 seconds to 56 seconds, and the number of prescribing errors from 4 to 2.³⁴

A study of over 50 000 drug–drug interaction alerts in CDS systems graded both the knowledge quality (inappropriate, potentially inappropriate, appropriate) and the display characteristics, textual information, and prioritization (poor, moderate, or excellent) and examined users' responses.³⁵ In two sites, override rates exceeded 80%, while in the third site, the rate was 53%. Alert acceptance was largely determined by the way in which the alert was displayed; neither the quality of the knowledge, nor the text of the message, significantly affected acceptance rates.

Effectiveness

A Cochrane review found evidence that in randomized controlled trials, computerized advice on drug dosage effectively increased the proportion of patients with plasma aminoglycoside concentrations within the therapeutic range, and in addition reduced the risk of nephrotoxicity.³⁶ The reviewers reported that such systems may also improve anticoagulation, but are not demonstrated to benefit the control of insulin, anaesthetic agents, anti-rejection drugs, or antidepressants.

An umbrella review of the benefits of adding CDS software to CPOE systems, commissioned by the US Agency for Healthcare Research and Quality, concluded that 'CPOE and CDS does not appear to reliably prevent clinical [adverse drug events] ... it remains a work in progress.'³⁷ Alert fatigue was identified as a major problem. The reviewers noted that where systems had reduced errors, they had used CDS systems with patient-specific alerts. A retrospective analysis of 811 prescribing errors that caused harm in Pennsylvania judged that

over one-fifth (21.5%, n = 174) of the serious prescribing errors were likely to have been ‘intercepted and therefore possibly preventable if CPOE with CDS were used.’³⁸

A final consideration, often overlooked, is that computer systems are not 100% reliable or secure,^{39 40} One case series of malfunctions in CDS systems included failure to trigger an alert to amiodarone when the internal code-number for amiodarone was changed; having found this error by chance, the investigators examined patterns of alerting, and detected three further malfunctions related to automatic alerts.⁴¹

Conclusions

Systematic studies of CPOE and CDS sufficiently large to demonstrate changes in rare events have not been yet conducted. Their benefits are offset by subtle, but sometimes important, unintended consequences. Although they are widely and increasingly used, and have clear advantages in ensuring legible and complete prescriptions, and a reduction in error rates, they have not yet generally been proven to reduce serious patient harm.

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